ENGINEERING CASE LIBRARY

ECL 46R*

Design of a 16mm Portable News Film Camera

at Beckman and Whitley, Inc.

In June of 1963 a contract was signed under which Beckman and Whitley, a subsidiary of Technical Operations, Inc., agreed to design and develop a new 16mm sound movie camera for the American Broadcasting Company. The camera was to be portable and to be ready for use at the Republican National Convention in July of 1964. Although the company was a major producer of high speed still cameras, it had no prior experience in developing movie cameras. In contrast to "home movie" cameras this camera was intended for strictly professional use, principally the making of on-the-spot movies for television showing. The limited market for such cameras was then largely dominated by the Mitchell Camera Company, whose camera is illustrated in Exhibit 1. Improvements considered desirable by Beckman and Whitley management included lighter weight (less than 25 pounds) and a less restricted view for the camera man (the existing cameras allowed only 90°). Mr. Larry Teeple, a senior design engineer at Beckman-Whitley, was assigned to the project.

Prepared in the Design Division, Department of Mechanical Engineering by David A. Horine under the supervision of Professor Henry O. Fuchs, with support from the National Science Foundation.

*Revised by Richard C. Bourne in July 1968.

Company History

Beckman and Whitley, the world's largest producer of high speed cameras, was founded in 1945 by two men, one having a technical and managerial background and the other being a skilled machinist. Their first product was a camera for photographing dog race and horse race finishes. In the late 40's, Beckman and Whitley became the first company to produce what is now known as a high speed camera. These cameras, which take pictures at the rate of 200 to 200×10^6 pictures per second, are used in research work to photograph events of very short duration, such as explosion shock waves. One of the company's cameras, the model 189 Synchronized Framing Camera is so widely used that the Smithsonian Institute has asked for one for its permanent collection.

Although high speed cameras continued to be the main product line, Beckman and Whitley diversified into several other areas of scientific instrument design. Among the products that the company presently markets are several types of meteorological instruments, heat flow transducers, and several laser devices. In 1962 the company became a subsidiary of Technical Operations Inc., a research group working in such areas as physical optics, photo chemistry, and atmospheric physics. A member of the B & W sales department stated that this was a mutually beneficial affiliation since B & W had needed a stronger research capability and Technical Operations had needed a manufacturing group to produce the products of its research.

In 1963, B & W employed five research scientists, five technicians, and 17 others engaged in production.

Early Development History

Most television news stories today are recorded on film with sound-recording movie cameras, rather than recording via television cameras. One reason is that television cameras and associated transmitting equipment weigh 50 to 60 pounds and are quite cumbersome for a man to carry. Another reason is that when TV cameras have a built-in transmitter to make them portable rather than a cable connection, they do not produce very good pictures due to transmission signal distortions. Finally, motion picture cameras are

sometimes more reliable, since they do not have as many components. Rapid film processing techniques have been developed so that motion pictures including sound tracks can sometimes be put on the air within 35 minutes after an event has occurred.

Beckman and Whitley's involvement in the design of television news film cameras began in March of 1963 at a board of directors meeting of the parent company, Technical Operations Inc. One of the board members, who was a vice president at ABC (American Broadcasting Company), mentioned that his company had a need for a better camera than the one developed several years previously for CBS (Columbia Broadcasting System) by the Mitchell Camera Company (Exhibit 1). He felt that the CBS camera had two serious deficiencies. It was uncomfortably heavy (25 pounds), and it restricted the cameraman's view to only about 90°.

In March of 1963, Mr. Teeple flew to New York to discuss ABC's requirements with their chief engineer, Frank Marx. Describing his viewpoint of the camera development, Mr. Teeple said, "Frank told me that his company had already begun to establish the specifications for a new camera. As a first step in doing this, they had hired some engineers from CBS who had worked with Mitchell on the existing camera. These engineers were able to provide the original specifications for the Mitchell camera together with some improvements that they felt necessary after watching the Mitchell camera in operation for a few years (Exhibit 2). One of them told me Mitchell's biggest problem was getting the CBS cameramen to define what they needed.

"Frank Marx suggested that we might be able to improve upon existing sound cameras by designing one that would have continuous, rather than intermittent, film motion at the place where the film is exposed. He was convinced that this would improve the sound quality of the magnetic recording system* by eliminating noise producing vibrations.

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*Presently, the best type of sound track for motion pictures is a magnetic strip on one edge of the film. Sound is recorded on this strip with a tape recording system.

"The logical way to design a continuous motion film camera would be to provide some mechanism that would cause the image to follow the film, and Frank thought that this would be an area where we could use our know-how in high speed rotating mirror technology. I was doubtful that our use of mirrors was an analogous situation, but I agreed to explore the matter further.

"One thing that I learned made this project seem ideal for our company. Bell and Howell Camera Company had made a market survey that showed that the total world-wide demand for these cameras was only 200 units. Though I thought this number was too low, it did indicate that we would probably have little or no competition.

"On the flight back from New York, I had made some sketches for a 16mm news camera as I then envisioned it (Exhibit 3). My design criteria were the ABC specifications and fairly obvious general camera criteria. These latter criteria were, for example, that the film supply and take-up reels should be mounted back to back on a common axis to minimize camera size and that the camera height should be minimal so that the photographer could have a full field of view."

With the approval of the company board of directors, Mr. Teeple and other B & W engineers studied further the camera design feasibility, consulting with specialists in optics and in magnetic sound recording. After three months, Mr. Teeple made a presentation of the Beckman and Whitley feasibility study to a staff member of the ABC engineering department. The presentation included discussion of the technical aspects of designing a camera and the demonstration of a wood model.

<u>The ABC Contract</u>

On the basis of the presentation and subsequent negotiations, ABC and B & W negotiated a "best efforts" contract in June of 1963. This contract specified that ABC would contribute a certain amount of money per month called a "progress payment" toward the cost of developing a new camera. If B & W found that it could not design a suitable camera, it had the option to

terminate the monthly payments at any time without paying a penalty. If a camera were finally designed, the contract specified that ABC would buy the first three prototypes. In return, ABC received the option to buy the first 50 cameras, if they were ever built.

"We were really not certain that we could design a good 16mm camera when we began our development," Mr. Teeple recalled. "Therefore, the 'best efforts' contract was to our advantage. The contract allowed us to establish, without penalty, check points in our design. These were points where we weighed the risks of spending more development money against the potential payoff of our camera. Since we were spending a lot of company funds along with the ABC money, we had to be able to take our shellacking and call it a day if we believed the risks were too high."

ABC and B & W decided to set July of 1964 as the target date for production of three prototype cameras, providing that the contract continued to that time. July was the month of the Republican Convention, and ABC believed that the convention would be a good place to test and demonstrate the new camera.

Upon receiving the contract, Mr. Teeple formed a team to do the initial designs. The team held weekly meetings to discuss and evaluate progress. Each team member was chosen with particular aspects of the camera in mind. The team consisted of the following:

1) Mr. Teeple - project leader
2) B & W technical director - optical design and applied physics
3) Consulting Engineer with experience in motion picture camera design - film transport and various mechanical problems
4) B & W specialist on rotating mirrors - tracking mirror design
5) B & W Physicist - optical design, mechanism analysis, liaison between team members
6) Consulting Engineer - tape recorder design
7) B & W Technician - drafting, mechanical designs

"After we worked out most of the mechanical details of our design, we hired a consultant (an industrial designer) from the Detroit School of Psychology to do the aesthetic and human factors work on the camera," said Mr. Teeple. "We showed him our breadboard designs and gave him relevant specifications and packaging ideas that had occurred to us. Appearance was an important consideration for even our first prototype since it was to be tested at the convention. Though it would just be a prototype, it would be seen by a number of potential buyers, and initial impressions are important. The industrial designer spent several days studying the motions of a professional news film photographer. This gave him an idea of the human factors problems to take into account in his design."

Problems with a Mirror System

The team agreed that the basic approach to designing a continuous film motion system would be to use a moving mirror to reflect an image from the lens to the moving film. By synchronizing the motion of the mirror with that of the film, the image could be made stationary with respect to the film for the duration of the exposure. It was hoped that this would meet the ABC specification that the camera's noise level be below 38 db at 3 feet from the camera. May of 1964 was chosen as the target date for completing design of the continuous motion device, and the team decided that the project should be terminated if this crucial design could not be worked out.

The first attempt used an oscillating mirror driven by an 8-lobe cam (Exhibit 4). A working model was built and found to be excessively noisy. Several attempts were made to reduce this noice, but none were successful. "I think that we might have been able to get rid of the noise with enough work," said Mr. Teeple, "but the system had a second problem involved with tolerances. The cam would have to be built with an accuracy of under ± 1/10,000 of an inch to meet the ABC specifications for image "steadiness", and this would be difficult to produce."

The second attempt at synchronization used an oscillating mirror driven by a rotating plate on which eight ball bearings were fastened (Exhibit 5). Unlike the cam, tolerances would be no problem with the rotating plate since

the ball bearings could be easily located on the plate with a jig borer. A model was built and again found to be excessively noisy.

After several unsuccessful attempts to solve the noise problem, the weekend before the deadline for the continuous film movement design arrived. "I decided to spend the weekend making one last effort to find a suitable design," Mr. Teeple recalled. The critique of the star wheel, he later concluded, had become resolved to three main points, as follows:

> "Silencing the design would mean use of plastic rollers or bearing shoes, which would be inherently vulnerable to dimension change with wear and impact."
>
> "Overall steadiness could be improved only with tighter tolerances; the prospect of this for production was not encouraging."
>
> "The whole setup was marginally expensive as well; the combination of high cost and operation of a system at the limit of its capability left us extremely vulnerable in the marketplace. The competition could counter with both price and technology moves, while we were unable to react to such moves."

"I tried to boil the problem down to its essential elements. The mirror motion should follow the film motion. Specifically, the motion of the mirror should synchronize with the motion of perforation number 3 (Exhibit 6). The number 3 perforation is the point at which projection equipment usually registers film for each frame. If this could be done, the system would inherently cancel the effect of dimensional variations between perforations, and we could get accuracy in location of the image on the film.

"Using this idea, I considered a spring loaded rocking mirror (Exhibit 7) which is driven by the number 3 film perforation during each exposure and returns to its original position by spring force between exposures. I calculated that the rocking mirror would have to track the film for .19 inches, or .0264 seconds, and then return to its starting point in .015 seconds.

"On the following Monday, I had a cardboard and balsa wood model of the mirror built. It seemed to work, so we decided to go ahead and build a prototype camera. We literally extruded a camera into existence in the following eight weeks and delivered our first prototype to ABC on July 7, 1964, in time for the Republican Convention."

Most of the B & W design team was present at the convention, where eight photographers used the camera. (Exhibit 8) A total of 8,000 feet of film were taken, and of this approximately 30 seconds was televised. "You could tell when our film appeared by the improvement in sound quality," Mr. Teeple recalled.

Design Evaluation and Redesigns

After the convention, the B & W design team met with five of the photographers and tried to determine what things should be changed or added to the design. The product of that meeting was a "punch list"; the first page of this three page list is shown in Exhibit 9. The punch list classifies design changes into three categories.

1. No cost items -- changes and additions paid for by the existing contract.

2. Cost items -- changes and additions not paid for in the existing contract and therefore done at added cost.

3. Accessories to be added to later cameras.

"We did not have the Mitchell Camera Company's problem of getting our customer to define what he (ABC) wanted," said Mr. Teeple. "The cameramen were more than willing to tell us what was wrong with our camera. Instead, our problem was one of judging which of our customer's requests were really important ones, and we tried to solve this problem by watching a number of camera news teams in action."

A few months later, a second prototype, incorporating the design changes suggested by the test at the Republican Convention, was used at the Democratic Convention by three more photographers. Again, a punch list was prepared (Exhibit 10) and design changes were made. A third camera was built in the summer of 1964. This new prototype was given a series of tests (Exhibit 11), modified on the basis of these tests, and then presented to ABC. Another punch list was prepared by the ABC design staff and B & W for this camera (Exhibit 12).

Development Engineering

After completion of the design changes suggested by the tests at the two conventions and the ABC design review, the project was turned over to the B & W Product Design Department. This department was given the responsibility of making the existing "proof of concept" design into a marketable item. Product design for the CM-16 was headed by a former chief engineer of the Mitchell Camera Company, Les Brown. Mr. Brown, a graduate in mechanical engineering from California Polytechnic Institute, had headed the design work on the Mitchell-CBS news camera.

"Mitchell Camera Company and most other motion picture camera companies have established very high standards for picture quality," Mr. Brown observed. "These standards have been, in effect, blinders for camera designers. They have caused most designers, including myself, to fail to look for design approaches that compromise image quality for some other desirable feature. The CM-16 continuous film motion system does not provide as much picture definition as does the Mitchell-CBS camera. However, some loss of picture definition is not very important when you consider the relative magnitude of the loss of definition in a television system."

Mr. Brown spent about one month acquainting himself with the CM-16. "This proved to be a fairly difficult job," said Mr. Brown, "since two of the three existing cameras were being retained by ABC, and the third was usually in the hands of our sales department. Furthermore, there were no major layout drawings of the camera at the time. All of the parts for the three existing prototypes had been fabricated from A-size sketches due to the time limitations involved in the contract."

Initially, Mr. Brown was asked to concentrate his efforts on just the film magazine section of the camera. Two other people were given the responsibility of doing preliminary product design work on the remainder of the camera. Mr. Brown soon found that this team arrangement was unsuitable. "At the existing stage of our work, I really needed to be able to see the design from a total aspect." he recalled. "As it was, we had too many problems in making each of our sections of the camera compatible."

At Mr. Brown's request, he was made sole engineer on the project in April of 1965, "One man would find it impossible to do all of the design work on a contract in the aerospace field, but in this case, I estimated that the camera contained only 300 parts that required detail drawings. From my experience at Mitchell, where I had kept a log of the amount of time that I spent on various tasks, I estimated that I could produce an average of three detail drawings per day if I could be assisted by two draftsmen."

Mr. Brown's time schedule is shown in Exhibit 13. In it, he indicates that he would first finish his work on the film magazine and then proceed to design the camera from the opposite end, starting with the optical system. Near the end of work outlined in the time schedule, Mr. Brown observed, "As with most time schedules, mine was an underestimation of the time required to do the job. However, even though my estimate was off by 50%, it did give me a general idea of the amount of work required."

In general, the work on a given assembly, shown in the time schedule, progressed as follows:

1. Basic calculations, where necessary
2. Layout drawings
3. Parts drawings
4. Hand fabrication of three parts per drawing.

In this manner, three prototype production cameras were built by the end of February, 1966.

While sample parts were being made, Mr. Brown determined the manufacturing processes to be used on production models. This was done by evaluating several methods of making each part in terms of dollars and cents and in terms of quality. For example, Exhibit 14 shows a cost analysis comparing the use of sand casting versus die casting to cast the camera body. This chart was prepared by obtaining cost estimates from several die casting and sand casting companies. The chart shows that die casting is the most economical method if 300 units, the estimated yearly sales, can be made in a run. Mr. Brown carries this analysis further by comparing the relative costs of machining a sand casting versus a die casting. He found that when machining is taken into account, die casting is more economical even when only 100 units are produced per year. In his cost analysis, Mr. Brown assumed that B & W would write off the cost of tooling over 300 units. Mr. Brown also examined the relative qualities of sand castings versus die castings and noted that die casting produced a lighter weight part with a better finish.

Final Testing

Beginning in November, Mr. Brown prepared a set of test specifications for the three prototype cameras. These specifications incorporated the original ABC specifications with additional ones based upon Mr. Brown's experience in camera design (Exhibit 15).

Life testing was not done on the camera for three reasons. First, Mr. Brown believed that the production prototype was similar enough to the prototypes used at the conventions that most of the operational problems had already occurred and had been corrected. Second, the cameras had a one year warranty. This allowed the company to get a feedback about the type of problems occurring. "The warranty period is really our life test, and I think that it is a better one than any we could simulate ourselves," said Mr. Brown. "We simply cannot duplicate all of the situations and environmental conditions in which our camera will be used. But our customers will certainly let us know about them." Third, Mr. Brown felt that his company could not afford to spend the time required for life tests due to the money that would be lost in sales during the test period. He observed that this was also the practice at Mitchell and at many other camera companies.

The production camera is shown in Exhibit 16.

Upon reflection about the program, in October 1966, Mr. Teeple wrote the following observations:

"As a matter of history, we now realize that

1. The rocking mirror approach to ciné recording had certain technological advantages over existing systems, but was not so overwhelming as to have a clearcut advantage in all aspects of photography. The idea had sufficient impact on the film industry to gain us considerable attention and support.

2. By far, the greatest amount of effort and expense were entailed in successfully adapting the camera configuration to operational requirements of the news-film people. Examination of the change lists shows that alterations were predominantly a) for reliability of operation, or b) for operator utility. These changes, of course, affected the time schedule of the program, the engineering and manufacturing effort, and the total expense of the program.

This is the penalty we paid for entering this business without prior experience. We'd never make any of these mistakes again."

Exhibits, ECL 46

1. Mitchell SSR-16 News Camera

2. ABC Target Specifications (3 pages).

3. Initial sketches by Mr. Teeple (2 pages).

4. Cam-driven rocking mirror

5. Bearing-driven rocking mirror

6. ASA specification for registration

7. Film-driven rocking mirror

8. Operation of prototype camera

9. Republican convention "punch list" (3 pages).

10 Democratic convention "punch list"

11. Test program.

12. Final "punch list" (2 pages).

13. Mr. Brown's time schedule.

14. Typical cost analysis

15. Inspection report form (2 pages).

16. Production model camera.

Mitchell SSR-16 News Camera

Exhibit 2: ABC TARGET SPECIFICATIONS

ABC ENGINEERS

TARGET SPECIFICATIONS

16MM NEWSREEL SINGLE SYSTEM MAGNETIC SOUND CAMERA

1. It is the intent of these specifications to describe a completely portable, professional type, 16mm picture and single system magnetic sound-on-film camera, designed in accordance with current good engineering practice and capable of producing maximum quality of both picture and sound for television newsfilm type production.
2. The camera and sound recording equipment shall conform with all applicable ASA Standards.
3. Configuration and balance shall provide for maximum ease in both hand held and tripod mount production operations. Design of a special body brace shall be considered for the hand held type operation, if required.
4. The camera shall be designed for operation with commercially available 16mm perforated one side, winding B, monochrome and color motion picture films, both with and without magnetic sound striping.
5. The camera shall operate satisfactorily at a synchronous speed of 36 ft./min. (24 frames/sec.) even after prolonged exposure to temperature ranges from minus 30°F, to 110°F.
6. Design shall provide the potential for interchangeability of motors of various types.
7. The camera shall provide means for indicating operating speed and measuring film footage.
8. The noise level of the camera shall not exceed 40 db (ASA "A" weighting) under any conditions of operation when measured with a standard sound level meter.

9. The film transport system shall be designed to avoid emulsion rubs, scratches, abrasions, emulsion and/or magnetic oxide pile-up and similar defects - both for the picture area and the magnetic sound stripe.

10. The film path shall be clearly visible with threading designed so as to be easily accomplished, with accurate picture and sound synchronization, by the average motion picture cameraman. Automatic threading shall be considered, providing it does not adversely affect other design characteristics and/or increase manufacturing cost to an unrealistic amount.

11. All amplifier and power connectors shall be of the positive locking type with all exposed terminals fully protected from possible damage.

12. An easily accessible provision shall be included for "inching" the camera mechanism by hand as a means of checking correct camera threading.

13. Provision shall be included in the film path to automatically turn off the camera in case of loop loss or film breakage during operation.

14. All magazines shall accommodate film rolls of increased diameter because of the magnetic sound stripe and shall accommodate rolls on standard film cores (with key-way) as well as daylight loading spools for both the feed and takeup sides.

15. Camera shall be designed for possible future use of a 1200 ft. capacity film magazine (tripod mount only).

16. The weight of the camera with motor(s), 400 ft. magazine and film (less lens, power supply and cables) shall not exceed 12.5 lbs. As above with 200 ft. magazine and film, weight shall not exceed 9.5 lb.

17. Position of the film plane at the aperture shall provide for optimum resolution throughout the entire film frame.

18. A fixed exposure time of 1/45 second shall be provided.

19. Vertical and horizontal unsteadiness of film motion shall not exceed a maximum of 0.1% of frame width.

20. Camera shall be designed for single lens mount of "C" type, wherein a zoom lens with integral reflex focus and viewfinder will be utilized. Design shall accommodate lenses of focul lengths from wide angle of 10mm (or less) to 20 inches.

21. Camera housing shall provide for potential use of an external, non-reflex type viewfinder in order to utilize all commercially available 16mm "C" mount lenses of fixed focal length.

22. Distance between the magnetic record and reproduce heads shall be a maximum of 2 film frames.

23. Both the record and reproduce heads shall be designed for a minimum of 1000 hours of operation.

24. The magnetic sound head assembly and its mounting shall be designed for interchange of the assembly in the field without requiring any adjustment and still give acceptable performance.

25. Frequency response shall be flat within $\pm$ 1 db from 50 to 12,000 cps.

26. Total r-m-s flutter and wow disturbance shall not exceed 0.2%.

27. Equipment design shall provide for a minimum of maintenance problems, particularly in relation to the relatively rough usage to which a television newsfilm camera is subjected. Complete operating and maintenance instructions shall be supplied in duplicate with each camera unit.

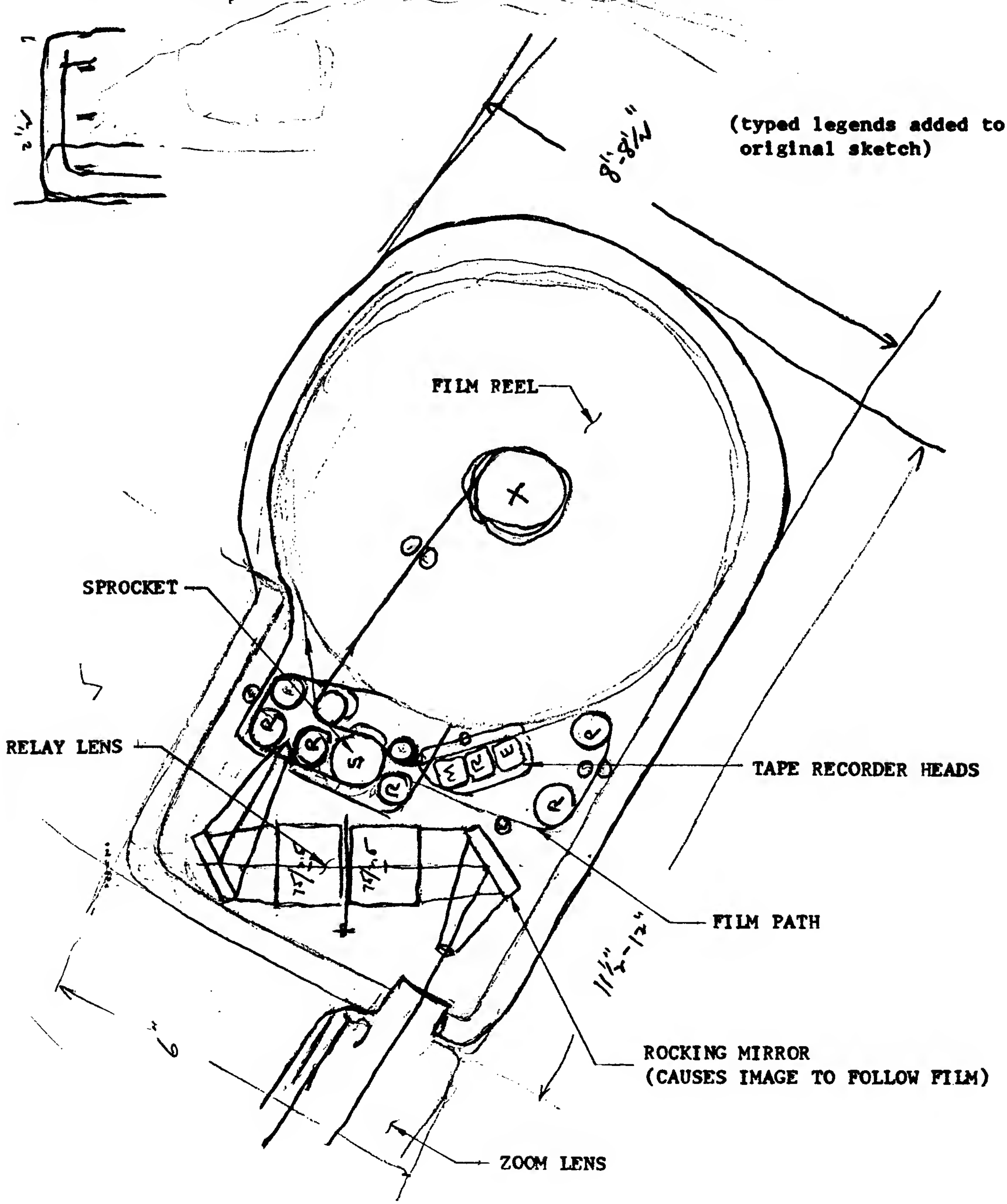
BW 335-357

Beckman & Whitley INC.

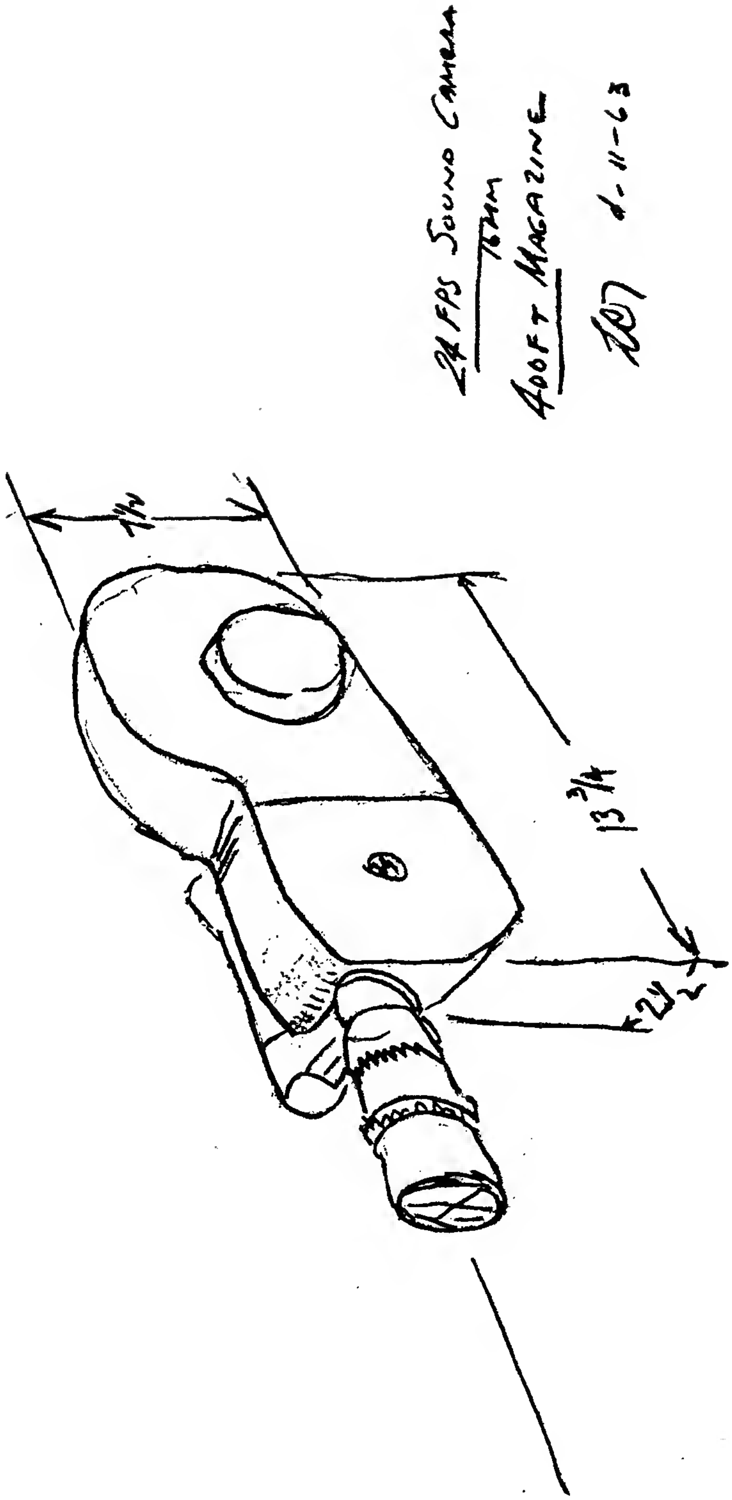
BY [illegible] 3-13-63 DEPT DATE

APV SHEET __ OF __ NO

SUBJECT 400 ft 16 mm Sound Camera ABC-TV



Initial Sketches
(page 1 of 2)



Initial Sketches
(page 2 of 2)

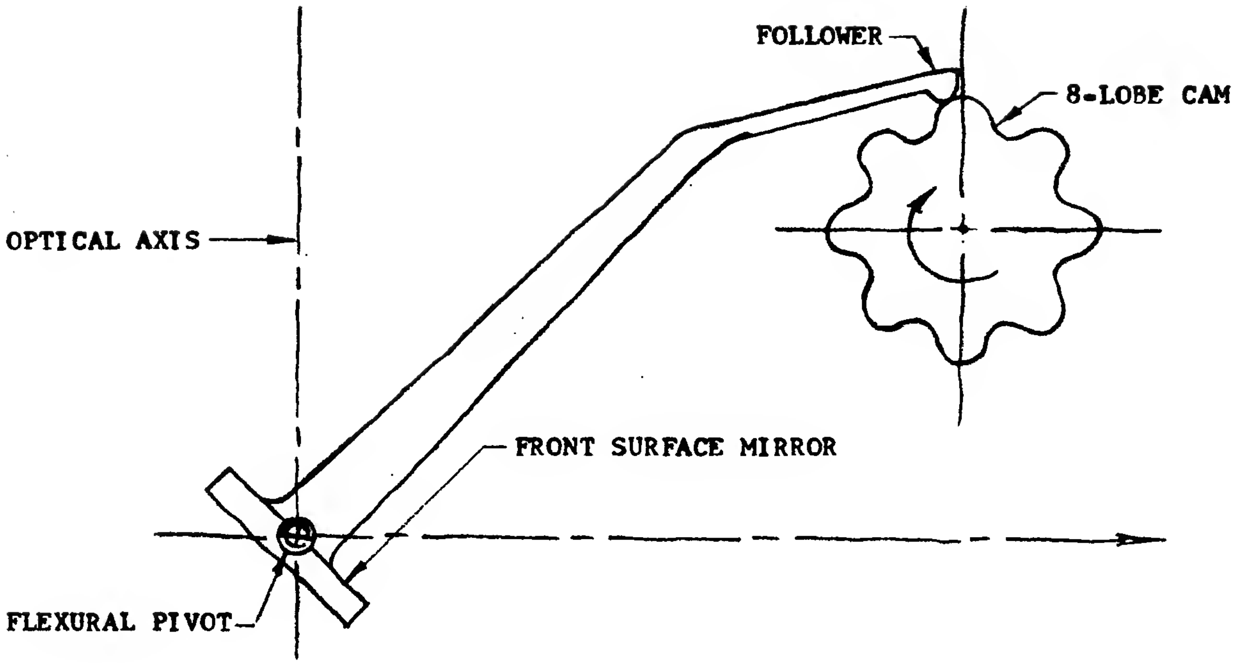


Exhibit 4: Cam-Driven Rocking Mirror

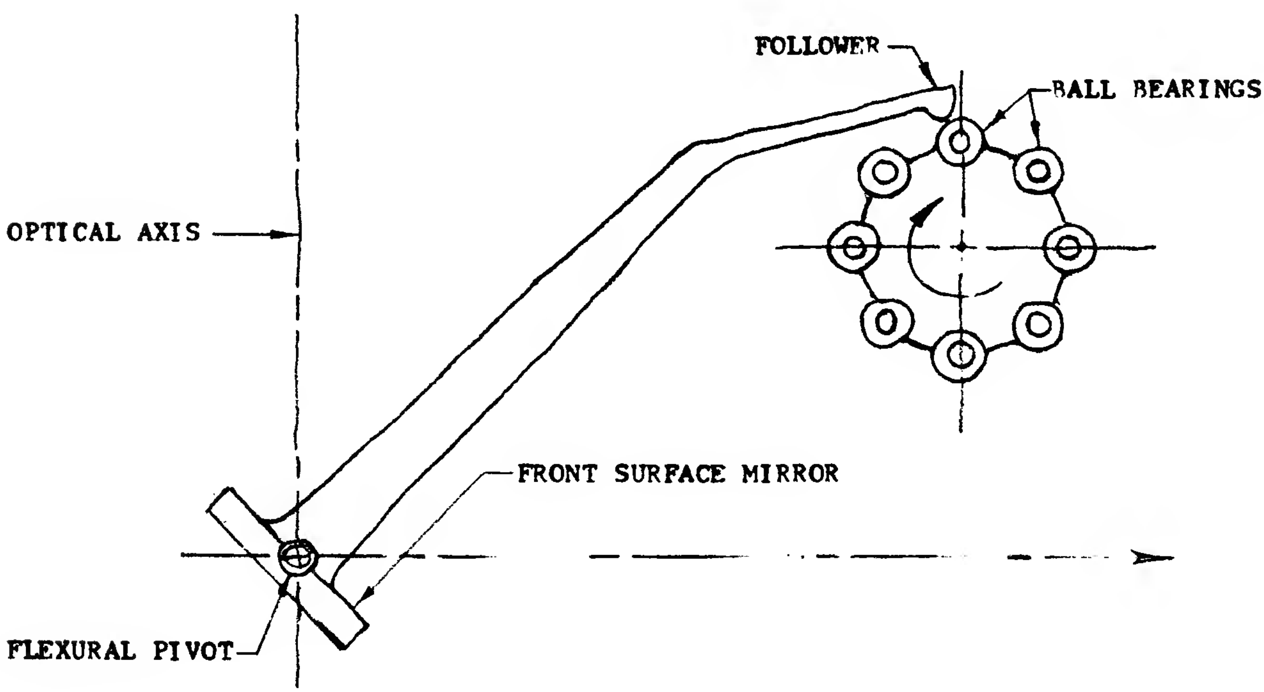
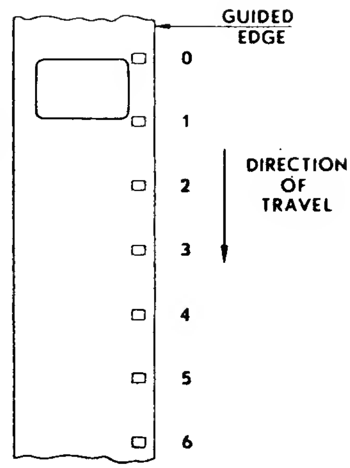


Exhibit 5: Bearing-Driven Rocking Mirror

Exhibit 6

ASA Specification: **Perforation 3 in the diagram is suggested as the preferred location for vertical registration...**



REP. FROM THE APPENDIX OF PH 22.8-1957

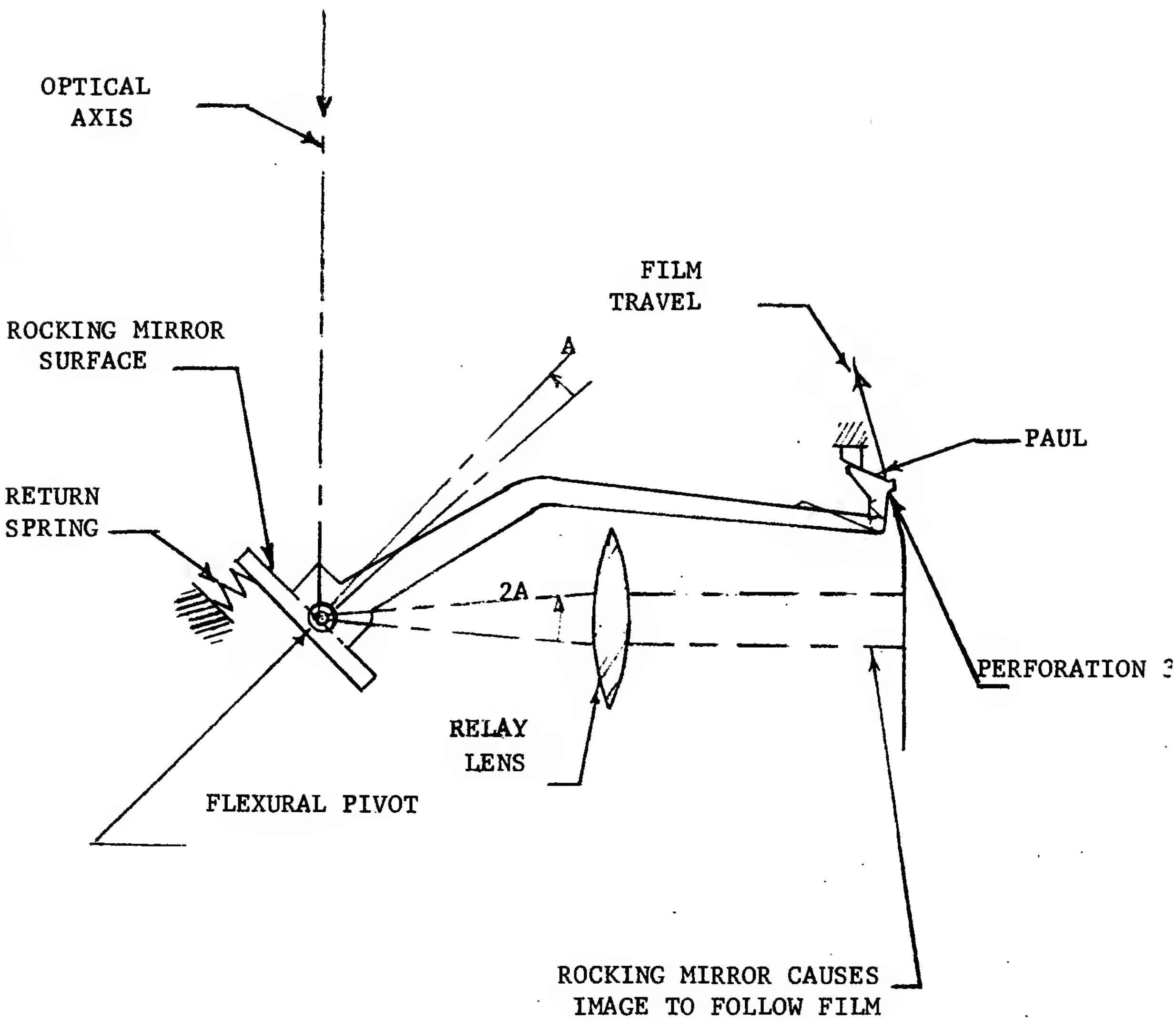


Exhibit 7: Film-Driven Rocking Mirror

Typical Mode of Operation of Prototype Camera (Soundman on the Left)

Changes
1

BW 335-357

Beckman & Whitley INC.

BY ____ DEPT ____ DATE ____
APV ____ SHEET __ OF ____ NO. ____
SUBJECT ____

No Cost items of 28 July Ltr.

Footage scale enlargement

Magazine filming face: correct film dishing

Aperture (internal) to f/22 —

Done

not possible w/ this diaphragm Pivot Sudy

Manual takeup knob on mag.

Operating switch changes

Magazine doors open 110° - spring loaded

Buckle switch installed

End of film "

Pawl adjustment for saw stroke

Supply rollers in mag corrected

Beef up nose of camera to prevent tip

Film track cleared of nicks & scratches

Marked Sound drum

New plugs - different for sound & power

Power cord 7 ft.

Permanent capstan lube

Heaters in camera & mag

Backstops on gate guide

Tachometer installed

Power pack latch reworked

Exhibit 9: Republican Convention "Punch List"
(Page 1 of 3)

Exhibit 9

ECL 46R

BW 335-357

Beckman & Whitley INC.

BY ______ DEPT ______ DATE ______
APV ______ SHEET __ OF ______ NO. ______
SUBJECT ______

Camera

Mitchell & Arri mount adapter, Pellicle reflex - viewers. — optional

4 Digit footage counter adjacent to tachometer — std

ok Rocker switch for camera actuation — std

Eval Pendant switch on AC line cord — std

ok Plug in preamp for cameraman sound monitor (internal) and long line operation. — optional

ok Miniature connector of headset for camera sound monitor from playback head. — optional

ok Captive film gate actuator. — std

ok Quick mount shoe for brace & tripod — optional

opt Adjustable hand grip - mount in tripod screw mount — "

ok Gate viewing magnifier — "

Snap-shot gate [INTERLOCK on Buckle] — std

(electronic) Heater operation on 14 V.D.C or AC - will op. on auto battery connection — std

ok Automobile lighter plug adapter cord — opt.

Interchangeable sound head assy for RCA, Bach Auricon, & B-W amplifiers — opt.

Rain covers, mag. covers, heater barneys — opt.

Dovetail located finder mount for fixed lenses — std.

Exhibit 9: Republican Convention "Punch List"
(Page 2 of 3)

BW 335-357 Chgs 3

Beckman & Whitley INC.

BY ____ DEPT ____ DATE ____

APV ____ SHEET __ OF ____ NO. ____

SUBJECT ____

Cost Items

Shorten zoom lens finder — cost item ?
Light lock on viewer — " " } Jens Mfr
Focus device — " "
Removable gate —— done in 1&2
Reduce power pack for 1 hr max
Snap on power pack
AC connector on power pack for double system
Battery charger for 50 or 60 cy — 110 or 220 v done - 1&2
Playback preamp for cameraman
Internal sequencing of sound leads
Internal Filters
Footage indicator on supply
Contoured hand grip Relocate handle
400 ft daylight spool accommodation
Core ejector
Change level indicator on batt pack done - 1&2
Improve latch design Prod only
Dust & rain tight mag & camera joint Prod des. 1

Exhibit 9: Republican Convention "Punch List"

(Page 3 of 3)

Exhibit 10 ECL 46R

BW 335-357

Beckman & Whitley INC.

BY RL DEPT ______ DATE 8/31/'64

APV ______ SHEET __ OF ______ NO. ______

SUBJECT Changes on #1 & #2

	what	who	priority
	– stops on all latches (bend stems)	B	2
(✓)	– take-up knob at other side	T(1) & B	2
	– footage counter	T & B	1
H	– motor with enough power.	H & B	1
	– other grip	T & B	2
(✓)	– internal f-stop	T & B & L (calibrate)	1
✓	– removeable gate.	L & B	1
✓	– tachometer rubber.	L & B	1
(✓)	– door at camera far side	L or T & B	2
✓	– gate-buckle switch interlock.	L & B	1
✓	– 45° rollers.	L	1
(✓)	– bar-effect	L	2
H	– double-system power packs	H	2
✓	– supply scratches	L & B	1
✓	– intake "	L & B	1
✓	– jump of take-up	L & B	1
	– spools slip sideways	T & B	1
	– teflon tape	B	–
✓	– film-heater interference	L & B	1
(✓)	– test heater system	L & H	2
✓	– clean gates	L & B	1
✓	– hard chrome back gate	L & B	1
✓	– click stops on gate	L & B	1
H	– μ-metal.	H & B	1
H	– clean-up wiring	H & B	2
✓	– shutter belt flanges	L & B	1
H	– cables huskier	H	2
✓	– instruction manual	L & T	2
	– stops & snaps on doors	T & B	2
(✓)	– quick release nut	T (L) & B	3
(✓)	– motor nut	T (L) & B	2

Democratic Convention "Punch List"

Exhibit 11 ECL 46R

BECKMAN & WHITLEY INC.,
San Carlos, California

9 October 1964

By: John K. Landre
Project Engineer
Photo Instruments

TEST PROGRAM - ABC CAMERAS

IN THE LAB.

1 & 2. Scratches, Emulsion Piles.

Run thru 5 rolls (1 hr.) of fresh film (different emulsions!) and look for scratches, sprocket hole tearing, emulsion piles, etc.

3. Image Quality (Target Shots).

Check for correct relay lens setting (sharpness)
Check for correct relay lens setting (image motion comp.)
Check f-stop calibration
Check for image steadiness, viewer coverage, frame line position.

4. Sound Quality.

Check hum and noise level (-45db?)
Check wow and flutter (with fresh film)
Check frequency response (with fresh film)

5. Low Temperatures.

Find temperature at which camera does not run up any more with heater disconnected.
Find why not (film, gears, etc.)
Check heater efficiency, on-off times etc., at 32°F, 20°F, 10°F and 0°F. Does camera start? Is image quality and sound quality (wow, flutter, noise) unaffected?
Same tests with camera and power pack at low temperatures; check motor voltage and power consumption (battery life).
Same with sound amplifier at low temperatures.

6. Durability

Run camera for 20 hours (10 rolls, 10 X each) and check for mechanical failures, pawl wear, tape head wear, etc.

7 & 8. Outside Durability and Handling

Shoot film, at least 400 feet, sound-on-film with:

Mr. Beckman (at home, i.e. alone?) one day or weekend.

KGO Crew	1 - 2 days
Bill Birdsey	1 - 2 days

While checking for weak spots in handling (instruction book!), mechanical breakdowns, electrical malfunctions, etc.

Exhibit 12

BECKMAN and WHITLEY, INC.

ECL 46R

"A"

MECHANICAL AND OPERATING ITEMS TO BE CORRECTED

BECKMAN & WHITLEY CM-16 NEWSFILM CAMERA

1. Film gate must "lock" closed with a positive acting gate interlock.
2. Film break switch is improperly adjusted - Please make foolproof.
3. Emulsion piles up in gate - Suggest you check front film gate channel width.
4. Slippage inherent in tachometer coupling method. More positive coupling is required.
5. The 400' magazine must take-up daylight spools and lab cores.
6. Footage counter must be adapted to lab core/daylight spool operation.
7. Sound cables must meet cold weather flex tests.
8. Charger to battery pack connectors unacceptable - pins and locks too flimsy, connectors not self-orienting.
9. Battery pack must operate at 30°F ambient (with heaters).
10. Battery pack must have externally mounted output voltage range switch.
11. Camera must have headset jack (internal playback monitor preamplifier).
12. Please secure the camera mounted connectors.
13. Manual take-up knob inoperative due to core lock.
14. Provide internal fine focus eyepiece.
15. 1200' Magazine must be provided for field testing entire system.
16. Provide quickmount "no hands" body brace design.

Exhibit 12: Final "Punch List"
12/23/64

BECKMAN and WHITLEY, INC.

"B"

RECOMMENDED REFINEMENTS TO BE INCORPORATED IN PRODUCTION CAMERAS FOR SALEABLE UNITS

BECKMAN & WHITLEY CM-16 NEWS FILM CAMERA

1. 400' Magazine take-up door spring should be at least 4 oz. stronger. Provide hold open springs on feed side door and camera door. All doors should open wider.
2. 400' Magazine feed side should take lab cores or daylight spools.
3. Footage counter scale on the 400' magazine should be enlarged. Scale should have divisions every 10 feet.
4. Positive click stops on internal aperture.
5. Provide a basic lightweight battery pack for running three 400' rolls 60°F.
6. Double system battery pack (2 frames accuracy in 1200').
7. Removable gate assembly should contain captive "Operator" knob.
8. State of charge indicator should be top mounted with GO/NO GO indicator.
9. AC/DC heaters should be easily fed by readily available sources, car batteries, Frezzo packs, Arri packs, dry cells, etc.
10. Charger should work 110/220 AC 6/12 volts DC.
11. Travel limits on magazine door locks.
12. Same connection to battery pack for all functions (charge/run).
13. Pack on "charge" should self switch to "Run" when camera is started.
14. Reduce size of charger.
15. Larger positive acting magazine "Bat Down Lever."
16. Big easy-grip manual take-up knob.
17. Positive camera door registration for demountable fixed focul length finders.
18. 12-240mm Zoom lens cradle.
19. Big GO/NO GO knobs and locks throughout.
20. Top and side numbers for magazine identification.
21. Quick mount, molded hand grip at bottom front with internal trigger.
22. Remove cast handle, replace with flat top strap.
23. Replace "bat"run switch with "rocker"on camera.
24. Discard finder rest on camera door.
25. Fitted rain and dust covers for outdoor use conforming to tripod mounted camera and magazine in 400' and 1200' configurations.

Exhibit 13

BECKMAN & WHITLEY

CINE PRODUCTS

ESTIMATED DESIGN SCHEDULE: CM-16

SUBMITTED BY: [signature]

APPROVED BY: L. P. Temple

DATE RELEASED: JUNE 11, 1965

REVISION 7 DATE OCT. 15, 1965

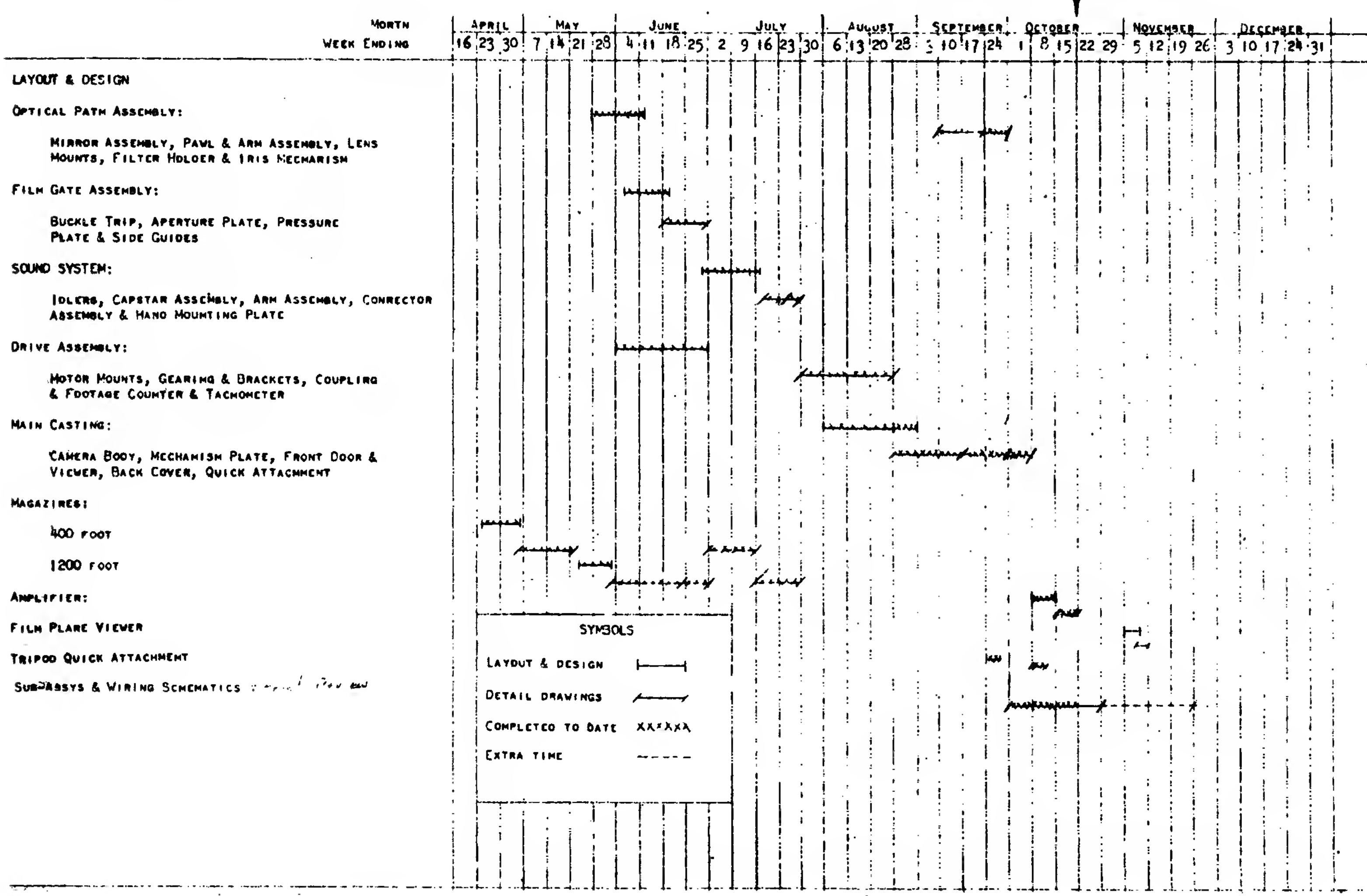


Exhibit 13: Mr. Brown's Time Schedule

Les Brown

CASTING COST

10/18/65

Die Cast

Name & Part #	Tooling Cost	300 Camera Write-Off	200 Camera Write-Off	100 Camera Write-Off	250 Lot PC Price	Set Up	300 Pcs	200 Pcs	100 Pcs
7D391 Camera Body	6380.00	21.30	31.60	63.80	1.85	50.00	22.01	33.65	66.05
7D392 Back Cover	5990.00	20.00	29.95	59.90	1.71	50.00	21.77	31.86	62.01
7D387 Front Door	3410.00	11.35	17.05	34.10	1.18	50.00	12.59	18.43	35.68
7D401 Base Plate	3325.00	11.00	16.62	32.25	1.09	50.00	12.15	17.91	34.74
Total Above (4) Castings	21,050.00	70.00	105.25	210.00	5.83	50.00	76.08	111.28	217.38

Sand Cast

Name & Part #	Tooling Cost	300 Camera Write-Off	200 Camera Write-Off	100 Camera Write-Off	250 Lot PC Price	Set Up	300 Pcs	200 Pcs	100 Pcs
7D391 Camera Body	285.00	0.95	1.42	2.85	23.75	—	24.70	25.17	26.60
7D392 Back Cover	230.00	0.77	1.15	2.30	24.85	—	25.62	26.00	27.15
7D387 Front Door	206.00	0.68	1.06	2.06	20.28	—	20.96	21.34	22.34
7D401 Base Plate	245.00	0.82	1.22	2.45	27.50	—	28.32	28.72	29.95
Total Above (4) Castings	966.00	3.12	4.85	9.66	96.38	—	99.60	101.23	105.04

Typical Cost Analysis

Exhibit 14

ECL 46R

BECKMAN & WHITLEY INC.

a subsidiary of Technical Operations, Inc.

Cable: BWINC

441 Whisman Road
Mountain View, Calif. 94040

1 March 1966

CUSTOMER	PURCHASE ORDER		PLANNING ORDER	SERIAL NO.
______________	Date Received:	__________	____________	_________
______________	Date Requested:	__________		
______________	Date Shipped:	__________		

FINAL INSPECTION REPORT - CM-16 NEWS CAMERA

Per Process Specification 7A001

1. RESOLUTION TEST:
   a) Lens _____ Serial No. "film clip attached"
   b) Edge _____ L/mm
   c) Center _____ L/mm

2. EXPOSURE COMPARISONS - DENSITY:
   a) Lens Iris _______ edge density _______ center density.

   b) Camera Iris _____ edge density _______ center density.

3. STEADINESS TEST - DOUBLE EXPOSURE:

   Horizontal and Vertical - Less than 0.15%
   a) Vertical _____% "film clips attached"
   b) Horizontal _____%

4. RADIATED SOUND:

   Max. 38 db at 3'.

   Level Recorded: Front: ______ db
   Viewer Side: ______ db
   Motor Side: ______ db
   Rear: ______ db

BECKMAN & WHITLEY INC.
Mountain View, Calif.

5. LIGHT LEAK TEST:

"film clips attached"

6. SCRATCH AND ABRASION CHECK

"see attached film"

7. POWER CONSUMPTION:

Not to exceed:

20 watts 400' Configuration; Record: _______watts

30 watts 1200' Configuration; Record: _______watts

8. MAGNETIC RECORDING:

a) Wow and Flutter:

(not to exceed 0.3 rms; .5 to 250 C.P.S.)

Recorded: _______ rms total.

b) Frequency characteristics:

Reproduces SMPTE test film M16MF flat with ± 1-1/2 db, 50 - 8000 C.P.S.

50 C.P.S. _______ db

400 C.P.S. _______ db

1000 C.P.S. _______ db

3000 C.P.S. _______ db

5000 C.P.S. _______ db

8000 C.P.S. _______ db

c) Recorder signal to noise ratio S/W _______

d) Film monitor signal to cross talk: S/C.T. _______

e) Idlers properly centered: _______

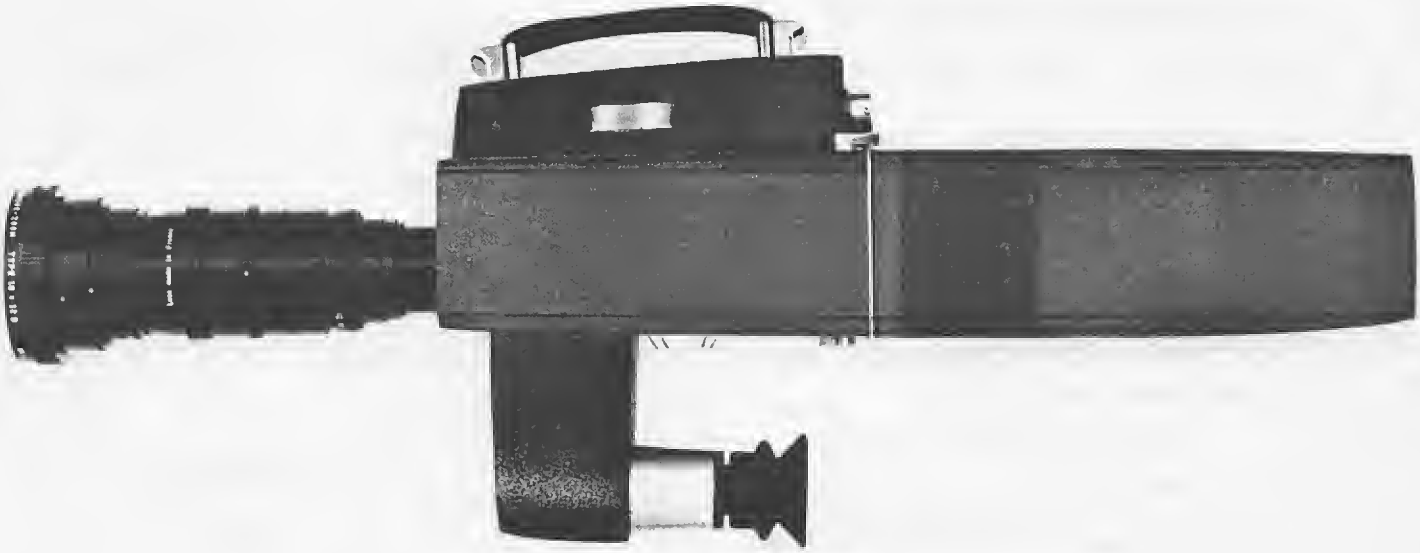
9. BUCKLE AND RUN-OUT SWITCH FUNCTIONING:

10. FILTER ALIGNMENT:

11. GENERAL WORKMANSHIP:

Chips, Scratches, Nicks, and Cleanliness.

Production Model Camera



Instructor's Note

Unlike the other eight cases in this design and graphics collection, the Beckman and Whitley Camera Development case has been used only as background for class discussions. It is included here for its value as an example of how work is organized and progresses on an engineering project of some complexity. There are a number of points in the case which might be emphasized in class discussions. The issues mentioned below are listed more or less chronologically as they appear in the case, rather than in order of importance.

1. When their need is urgent, one company may support a second firm's development of a product to satisfy that need. Many students will have thought that only the government and various foundations supplement product development costs.

2. When a company begins development of an entirely new product, they often hire personnel who have worked on a similar project. In this case we see ABC hiring several Mitchell engineers, and Beckman-Whitley relying heavily on Les Brown, who had headed development on the earlier Mitchell camera.

3. Work on a project of this type is usually carried out by a design team, made up of experts on various individual components, and a project manager or leader, whose primary job is to co-ordinate the work of the team members. On still more complicated projects, a project manager co-ordinates the work among group leaders, each of whom carries responsibility for a certain area of the project and supervises the work of the design engineers in his "group".

4. Design and development is an iterative and time-consuming process. This may well be the most valuable fact one can learn from this case. Many people picture engineers as designing a device once, perhaps making a few minor changes, then finishing the new design a few months after first tackling it. In contrast to that misconception, the Beckman and Whitley camera goes through five design iterations that we know of, and at least forty months of development before reaching the production stage. The number of changes made from prototype to prototype testifies to the importance of iteration.

5. Hard work is probably more important to the ultimate success of the development project than bright ideas. It might be valuable to get the students' opinions on the relative worth to the company on this project of Mr. Teeple and Mr. Brown, and then ask them whose job they would rather have. Both men, of course, contributed a great deal to the project; the show of hands on the last question is likely to reveal why engineers like Les Brown are harder to find.

The chronology of the case also emphasizes the importance of the development stages as compared to the concept phase; only about 5% of the total project time was devoted to the latter.

It is interesting to see, in the summer of 1968, the publicity that ABC is giving to the "new, lightweight cameras" which they claim will give their network superior coverage at the political conventions. NBC considered this enough of a threat to broadcast a rebuttal by David Brinkley: "It's not the technology that counts, it's the quality of the reporters."